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SUBJECT: Proposed Computational Procedure for the ORR Reactor-
Beam-Hole Shielding

TO: J. A. Cox

FROM: S. K. Penny

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OAK RIDGE NATIONAL LABORATORY

January 28, 1958

To: J. A. Cox

Subject: Proposed Calculational Procedure for the ORR Reactor Beam-Hole Shielding

Herein is described a proposed calculational procedure for the ORR reactor beam-hole shielding. Also listed are the assumptions involved and the known uncertainties.

The calculation involves penetrations of both neutrons and gamma rays from 12 - 20 mean free paths deep. Besides the limited knowledge of deep penetration calculations, little is known about the radiation source except that it is the leakage from a reactor similar to the TSR and is well collimated. The "buildup factor" concept is not too valid, first because the geometry is ill suited and second if buildup factors are mentioned then energy spectra of the radiation must be mentioned. The energy spectra are not known. Thus one is forced to use as simple a model as possible and try to be conservative whenever possible.

The method that is proposed is the "comparison method." It is a normalization of known dose rates from a given source to obtain an estimate of the source strength for the unknown source. The assumption involved is that the given source and the unknown source be nearly alike in the radiation energy spectra and angular distributions. The dose rates from an experiment with well-collimated radiation at the TSR will be used to obtain an estimate for the ORR reactor beam-hole source. The experiment at the TSR involved an 8-in.-dia collimator in line with the TSR and the measurement was taken at 64 ft from the center of the reactor tank. There was 42 cm of H₂O between the collimator and the reactor as opposed to the 3 in. of Be at the ORR reactor.

Calculations were made using tolerance dose rates suggested by Roy L. Clark, the dimensions of a beam hole similar to that proposed by S. W. Peterson and H. A. Levy (Fig. 1), and a reactor power of 30 Mw. The direct-beam dose rate was calculated on the centerline of the beam hole and the scattered dose rate was calculated on the assumption that all the radiation was scattered isotropically at A₃ (Fig. 1). Ordinarily one might use a removal cross section for the neutron attenuation in both the direct beam and scattered beam even though the concept is not valid in shield configurations and geometries not similar to those in which the

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cross section was measured. However, in lieu of being ultra-conservative in the direct-beam calculation a total neutron cross section evaluated at ~ 8 Mev was used without buildup.* This is somewhat justified since the direct beam is so well collimated that any interaction will essentially remove it from the beam. The same reasoning should apply as well to the gamma-ray direct-beam calculation. The scattered neutron beam was calculated using a removal cross section which carries along its uncertainties in application and in numerical value. The one place where one might justifiably use a buildup factor is in the gamma-ray scattered beam since the geometry is almost suitable. The scattered gamma rays are degraded in energy which means the average cross section would probably increase. However, without the knowledge of the energy spectrum after scattering it would be nearly impossible to apply the buildup factor concept. Therefore, no buildup factor was used for the scattered gamma-ray beam and the same total cross section was used as that for the direct beam.

The equations, numerical values, and results of the calculation are in the following pages.

In passing, note that the estimated neutron dose rate at the outer side shielding edge through a measurement hole is 1 rep/hr assuming 20%[†] of the neutrons are scattered.

This is a proposed calculation and a suggested tolerance dose rate was incorporated. If the thicknesses are too large one might look at other tolerances.

Keith Penny

KP:vg

*Private communication, E. P. Blizard.

†Private communication, C. E. Clifford.

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Figure 1.

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Direct Beam

$$(1) \quad \frac{D_{\text{ORR}} l_{\text{ORR}}^2(x) A_{\text{TSR}} e^{\Sigma_{\text{ORR}}^x + \Sigma_{\text{Be}} \cdot 7.62} P_{\text{TSR}}}{D_{\text{TSR}} l_{\text{TSR}}^2 A_{\text{ORR}}(x) e^{\Sigma_{\text{H}_2\text{O}} \cdot 42} P_{\text{ORR}}} = 1$$

Scattered Beam

$$(2) \quad \frac{D_{\text{ORR}} (l'_{\text{ORR}})^2 A_{\text{TSR}} 4\pi y^2 e^{\Sigma_{\text{ORR}}^y + \Sigma_{\text{Be}} \cdot 7.62} P_{\text{TSR}}}{D_{\text{TSR}} l_{\text{TSR}}^2 A_1 A_2 P_{\text{ORR}} e^{\Sigma_{\text{H}_2\text{O}} \cdot 42}} = 1$$

$$D_{\text{ORR}} = \text{dose rate at ORR} \leq \text{tolerance} = \begin{cases} .125 \text{ mr/hr gammas} \\ .0125 \text{ mrep/hr neutrons} \end{cases}$$

$$\frac{D_{\text{TSR}}}{P_{\text{TSR}}} = \begin{cases} 1.5 \times 10^{-3} \text{ mrep/hr-watt neutrons} \\ 1.5 \times 10^{-1} \text{ mr/hr-watt gammas} \end{cases}$$

$l_{\text{TSR}}, l_{\text{ORR}}$ = distance from reactor denoted by subscript to point where dose rate is known or calculated,

$$l_{\text{TSR}}^2 = 3.666 \times 10^6 \text{ cm}^2,$$

$$A_{\text{TSR}} = \text{area of TSR collimator} \\ = 16\pi \text{ in.}^2,$$

x = ORR direct-beam shield thickness (Fig. 1),

$A_{\text{ORR}}(x)$ = area on ORR reactor as seen from x ,

$$\frac{l_{\text{ORR}}^2(x)}{A_{\text{ORR}}(x)} = \frac{(l_{\text{ORR}}'' + x)^2}{A_2},$$

l_{ORR}'' = distance between A_2 and dose rate point x on centerline of collimator (Fig. 1)

$$= 309.88 \text{ cm},$$

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$$A_2 = A_3 \\ = 4 \text{ in.}^2 \text{ (Fig. 1),}$$

$$A_1 = 16 \text{ in.}^2 \text{ (Fig. 1),}$$

$$l'_{\text{ORR}} = \text{distance between } A_1 \text{ and } A_3 \text{ (Fig. 1)} \\ = 198 \text{ in.,}$$

$$P_{\text{ORR}} = \text{maximum power of ORR reactor} \\ = 3 \times 10^7 \text{ watts,}$$

$$\Sigma_{\text{H}_2\text{O}} \cdot 42 = \begin{cases} 6.1 \text{ neutrons} \\ 1.05 \text{ gammas} \end{cases}$$

$$\Sigma_{\text{Be}} \cdot 7.62 = \begin{cases} .99 \text{ neutrons} \\ .1905 \text{ gammas} \end{cases}$$

$$y = \text{scattered beam shield thickness,}$$

$$\Sigma_{\text{ORR}} = \text{macroscopic cross section of shield material,} \\ = \begin{cases} \text{total cross section at } \sim 8 \text{ Mev neutrons direct beam} \\ \text{removal cross section neutrons scattered beam} \\ \text{total cross section at } \sim 6 \text{ Mev gammas direct and scattered} \\ \text{beam.} \end{cases}$$

Change symbol for total cross section of gamma rays to μ .

Substitution of numerical values in Eqs. (1) and (2) are taking logarithms:

Direct Beam

$$\Sigma_t x + 2 \ln (309.88 + x) = 32.790 \text{ neutrons}$$

$$\mu_t x + 2 \ln (309.88 + x) = 30.843 \text{ gammas}$$

Scattered Beam

$$\Sigma_R y + 2 \ln y = 22.455 \text{ neutrons}$$

$$\mu_t y + 2 \ln y = 20.508 \text{ gammas}$$

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	Brookhaven Concrete	Concrete Proposed by Glenn	Barytes Concrete	Brookhaven Concrete With Iron Replaced By Brass	"Glenn Concrete With Iron Replaced By Brass
$\mu, \text{ cm}^{-1}$	0.1269	0.1304	0.1088	0.1284	0.1311
$\Sigma_R, \text{ cm}^{-1}$	0.1350	0.09505	0.09090	0.1290	0.09242
$\Sigma_t, \text{ cm}^{-1}$	0.1768	0.1346	0.1193	-	-
Direct Beam	58 in.*	60 in.	67 in.	-	-
Scattered Beam	39 in.	52 in.	55 in.	40 in.	54 in.

*Shield determined by gamma rays.

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